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THE ROLE OF VISUALS IN VERBAL LEARNING--STUDIES IN TELEVISED INSTRUCTION, REPORT 3, SUMMARY REPORT.

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THE INTEGRATION OF WORDS AND PICTURES IN THE TWO STUDIES REPORTED IN THIS VOLUME WAS ACCOMPLISHED UNCONVENTIONALLY. IN ONE STUDY, AN ENTIRE TOPIC, ARCHIMEDES' LAW, WAS COVERED IN A SELF-CONTAINED, ENTIRELY PICTORIAL LESSON AND ALSO IN A SELF-CONTAINED, ENTIRELY VERBAL LESSON. STUDENTS ACQUIRED ALL THE CONCEPTS AND PRINCIPLES MAKING UP ARCHIMEDES' LAW FIRST ON THE BASIS OF ONE LESSON AND THEN ONCE AGAIN ON THE BASIS OF THE SECOND. IN A SECOND STUDY INVOLVING A LESSON ON PRESSURE, ONLY ONE OR TWO CONCEPTS OR PRINCIPLES WERE COVERED IN EACH VISUAL SEGMENT AND THEN AGAIN IN EACH VERBAL SEGMENT. IT REQUIRED ALL FIVE VISUAL SEGMENTS IN THE LESSON TO TEACH ALL THE CONCEPTS AND PRINCIPLES. SIMILARLY IT TOOK ALL FIVE VERBAL SEGMENTS TO TEACH ALL THE CONCEPTS AND PRINCIPLES. THE ONLY DIFFERENCE BETWEEN THE TWO STUDIES WAS THAT THE LESSON IN THE SECOND STUDY WAS SEGMENTED. WHAT WAS COMMON TO BOTH STUDIES WAS THE PROVISION FOR THE ACQUISITION OF THE DISCRIMINATIONS AND GENERALIZATIONS UNDERLYING THE CONCEPTS AND PRINCIPLES TO BE TAUGHT SOLELY ON THE BASIS OF PROGRAMED VISUAL MATERIAL, AND THEN ON THE BASIS OF BOTH SETS OF MATERIALS COMBINED. OTHER REPORTS IN THIS SERIES HAVE ACCESSION NUMBERS ED 003 211 AND ED 003 212. (LP)

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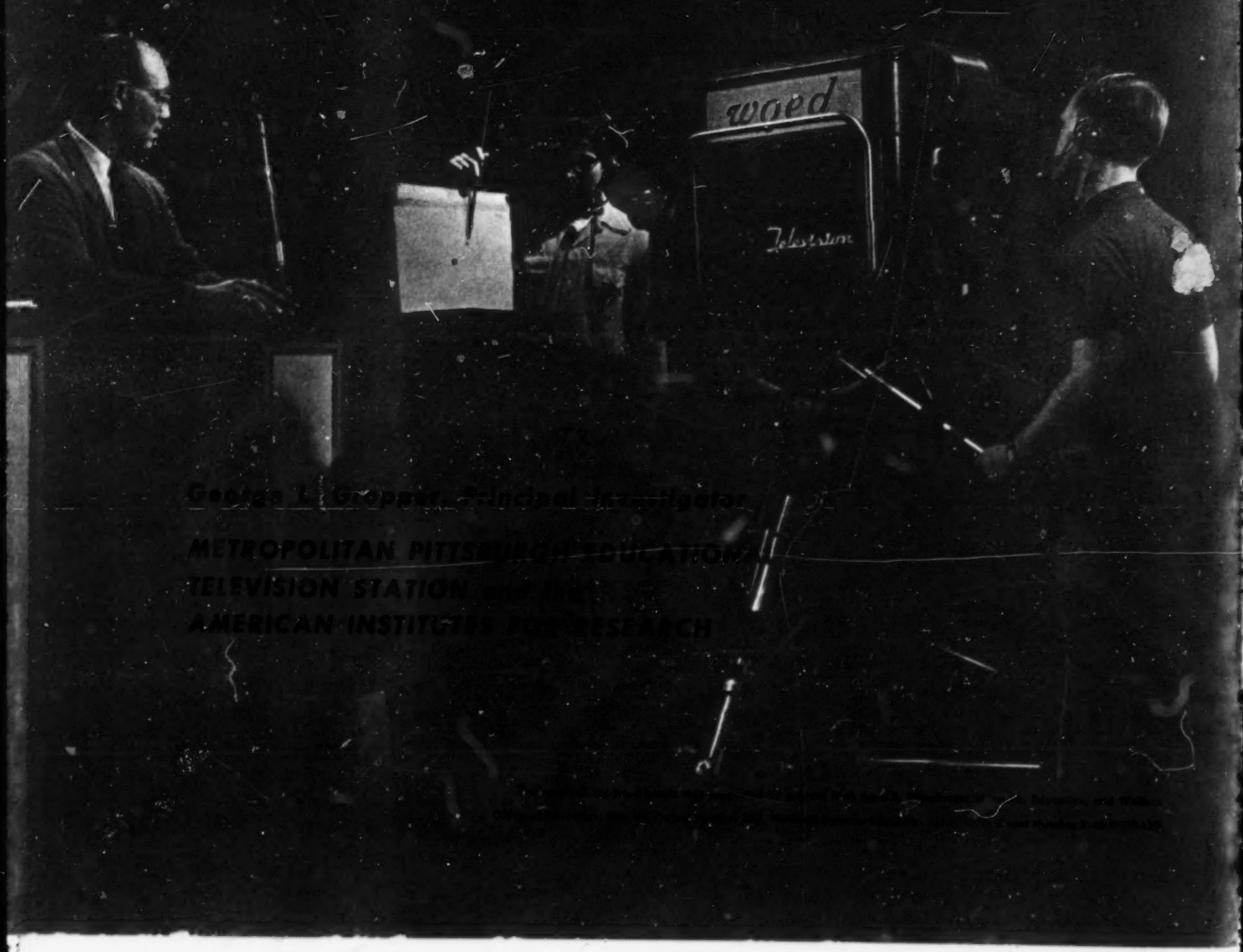
A SUMMARY REPORT



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STUDIES IN TELEVISED INSTRUCTION
the role of visuals in verbal learning

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A SUMMARY REPORT

George L. Gropper, Principal Investigator

METROPOLITAN PITTSBURGH EDUCATIONAL TELEVISION STATION and the
AMERICAN INSTITUTES FOR RESEARCH

October 1965 - Pittsburgh, Pennsylvania

FOREWORD

The research on visuals described in this volume was performed under a grant from the U. S. Department of Health, Education, and Welfare, United States Office of Education, grant number 7-48-0000.120, Project 637, under title VII of the National Defense Act of 1958.

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George L. Gropper
AMERICAN INSTITUTES FOR RESEARCH
October 1965

EXPLANATORY MODELS FOR VISUAL INSTRUCTION

Even though there are obvious qualitative differences between pictorial and verbal modes of instruction, both share a common objective. By means of either mode, the educator seeks to create a learning experience that will bring about a change in behavior. Audio-visual specialists who have theorized about how such changes might be brought about have tended to adopt one of two approaches. One group has concentrated on the qualitative differences between words and pictures and has accordingly not seen fit to adapt learning theory models, available for describing verbal learning, for interpreting learning from pictures. This group has specifically developed communications or information models to account for learning from pictures. A second group has sought to de-emphasize the differences between words and pictures and to emphasize the similar roles they play in instruction. It has accordingly preached the applicability of available theories of learning to both (see Symposium edited by Meierhenry, 1961). This polarization of views is similar in some respects to that occurring in such recent developments in instruction as "programmed learning."

As Klaus (1965a) points out, programming techniques tend to be either stimulus-centered or response-centered. The former tend to be almost exclusively concerned with the meaning, structure, or organization of stimulus materials. The latter are concerned primarily with responses and with the conditions, including the design of stimulus materials, that insure adequate response practice. The former tend to be either atheoretical or configurationist in viewpoint. The latter tend to be connectionist (S-R) in viewpoint. In the case of programmed instruction, the latter point of view, as measured by the number of adherents, tends to be dominant. In the case of audio-visual instruction, the polarization in audio-visual explanations tends to parallel that just noted, with one difference. The stimulus-centered (information or communications) point of view tends

to dominate. Unlike the learning approach, which stresses the behavior to be changed and practice conditions for bringing such changes about, the stimulus-centered approach in audio-visual instruction tends to be primarily concerned with the design of the message.

Audio-visual research on procedural learning and on motor learning has, it is true, been interpreted by some within a behavioral, S-R framework (e.g., Miller, 1957; Sheffield & Maccoby, 1961). However, empirical research in connected-discourse subject matters presented by audio-visual means has generally been interpreted by most audio-visual specialists within the framework of an information or communications model; (see Travers, 1964 for a review of such research). Most theoretical discussions in the same area also have tended to be "information" or "message" based (e.g., Hoban, 1960).

Choice of either approach to account for learning from pictures makes a difference in how research on audio-visual instruction prospers, for it dictates: the kinds of explanations a model offers; the issues that are considered important and therefore investigated; and where it looks for its data. "Information" models lead to research on questions about: the redundancy of a message; the relevance of a message; the capacity of visual and verbal channels for transmitting the message; etc. Behavioral learning theories are more apt to be concerned with: the analytic and dimensional analysis of variables that promote the acquisition, retention, and transfer of specific behaviors; the effect of visual and verbal modes of stimulus presentation on the acquisition of discriminations, generalizations, or chains, which are often described as the basic processes in all learning (Gilbert, 1962); the effect these different modes might have on such varied learning tasks as problem solving, learning of concepts, acquiring perceptual-motor skills; etc. "Information" approaches tend to rely for data on end-of-instruction achievement tests. Behavioral approaches, in addition, tend to rely for data on responses made overtly, explicitly, and actively <u>during</u> visual presentations. Asking different questions, the two different models obviously produce and provide the practitioner with different practical answers.

It is also true that some audio-visual discussions have borrowed explanatory concepts and terminology from both an information and a behavioral framework. Thus, in a discussion of "communications" transmitted through either the audio or visual channel, such S-R learning theory considerations as generalization from learning situation to testing situation are invoked (Hartman, 1961). Or, "response practice" or participation may be stressed (Ryans, 1963) even though the basic model is an "information" model that has no integral principles to account for its need. What are the consequences of such eclecticism for the growth of audio-visual theory and practice?

The explanatory and predictive capabilities of a theory increase as its laws begin to encompass an increasingly larger range of phenomena. Practical problems in turn are more apt to be solved as theory grows and becomes more comprehensive. A resort to selective borrowing from more than one theory to account (ad hoc) for particular phenomena within audio-visual instruction, thus, is neither likely to serve the advancement of either learning theory or of information theory; nor is it likely to make their practical implementation more widely useful or successful.

At present, supported by considerable empirical research, behavior theory encompasses a large body of explanatory principles that can account for a broad range of behavioral changes. It is reasonable to expect that they can account for the changes that define learning from pictures. As Postman (1961) has pointed out, "the process of audio-visual education does not call for the formulation of special principles; it calls for the application and elaboration of the general laws of human learning." The present study, concerned with the learning of concepts through visual (pictorial) presentations, has accordingly attempted to limit the variables chosen for study to those stemming from a behavioral model and to interpret the results observed within such a framework. The decision to take this approach is based on the premise that learning theory provides the sturdiest foundation on which to base an interpretation of "learning from pictures."

The behavioral way of looking at learning requires that the process be treated analytically; that the responses to be shaped at any point during an audio-visual presentation (not just end-of-course performance on an achievement test) be identified specifically; that the stimuli that are effectively to elicit them also be specified; and that the conditions of the pairing of stimulus and response be identified and arranged systematically so that the acquisition, retention, and transfer of the desired behavior will be facilitated. Such is the prescription of a behavioral model. One consequence of the failure to make such precise specification, is the uncertainty as to what it is in our presentation that actually brings about a change in behavior. The prescription applies equally well to learning from words or from pictures.

A further practical requirement of a behavioral approach is the precise description of the behavior to be changed. This is generally referred to as a definition of objectives. Its execution is important for two reasons. A comprehensive statement of objectives is necessary in order to: (a) determine whether students actually can do what a learning experience was designed to teach them; and (b) formulate an instructional strategy for building a learning experience that will bring about desired behavioral changes.

The goals of instruction are quite varied and, while words or pictures might be suitable in one instructional strategy, they might not be in another. The goals or objectives of instruction might consist of, according to one taxonomy of behavioral objectives (Gagné, 1965), (a) identifications; (b) knowledge of principles; (c) following procedures; (d) making decisions; or (e) performing skilled perceptual-motor acts. If a picture is truly worth a thousand words, is this value likely to be invariant for all these types of learning? Even within any given type of learning task is the value of pictures likely to be invariant? Thus, research on learning from pictures, as well as practical applications of audio-visual principles, must pay due, analytic attention to the various types of learning, to the specific behaviors to be shaped, and to the strategies that can accomplish these objectives.

The point of view being expressed here was described in preliminary fashion in an earlier article entitled, "Why is a picture worth a thousand words?" (Gropper, 1963b). It received concrete application in a film entitled, "Learning from Visuals: The application of programming principles to visual presentations" (Gropper, 1963a). The behavioral way of looking at "learning from visuals" is now given empirical support in this paper summarizing two research studies. The paper also offers further suggestions from a behavioral point of view as to some of the roles visuals can play in instruction.

The two studies undertaken in this project have adopted and extended the technology that has developed in programmed instruction (one behavioral model) to pictorial presentations. They have accordingly been concerned primarily with: (a) techniques for bringing specific responses under the control of specific visual stimuli; and (b) the use of visual stimuli possessing such control within the framework of an instructional strategy designed specifically for one kind of learning task: the acquisition of concepts and principles.

Study No. 1: An Investigation of Response Control During Visual Presentations

Study No. 2: Integrating Visual and Verbal Presentations

Both studies, described in detail elsewhere,[1] were in the main concerned with how visual demonstrations might be best used to teach science concepts and principles. One study sought to teach Archimedes' Law, the other concepts having to do with "force" and "pressure." Both studies involved the preparation of programmed visual demonstrations and programmed verbal materials. One study relied on a complete, solely visual lesson to teach concepts and principles. This was then integrated with a solely verbal lesson also designed to teach the same concepts and principles. The solely visual lesson was shown in its entirety either before or after the verbal lesson. In the second study, visual and verbal lessons were divided into small segments, with each segment devoted to a few concepts. Their integration was accomplished through the serial intermixing of visual and verbal segments. It is this latter study that provides a paradigm for the optimal integration of the single concept film (presented in pictorial terms) and other forms of instruction (programs, lectures, seminars, etc.). It also offers a paradigm for the integration of visual and verbal materials in a single integrated film or television lesson.

Verbal programs used in the two studies were typical linear programs requiring constructed responses; the responses required became increasingly longer and more complex. The visual programs presented on TV constituted a departure from conventional uses of visuals in instruction and represent a different form of programming. Each program or program segment was designed to teach the discriminations and generalizations that underly the concepts and principles to be taught. For example, following the

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[1] Gropper, G. L. Controlling student responses during visual presentations - Report No. 2. Studies in televised instruction: The role of visuals in verbal learning. Study No. 1 - An investigation of response control during visual presentations. Study No. 2 - Integrating visual and verbal presentations. Pittsburgh: American Institutes for Research, October 1965.

presentation of a demonstration of the difference between an object's weight in air and in water (a discrimination or distinction to be acquired), the student was expected to predict the apparent change in weight that would occur for another, different sized object. By being exposed to a variety of such practice opportunities, the student acquired the generalization for <u>all</u> objects (that there is a change in scale readings when objects are first weighed in air and then in water). Students selected their answers from multiple-choice pictorial options. Based on such practice, all concepts were acquired in both studies on the basis of programmed visual demonstrations. The accompanying verbal material served to provide the more technical language a scientist might use in explaining the same phenomena.

This was the general approach used in both studies. Each study was devoted to other separate issues. These will be discussed, as they apply, in the sections that follow.

ACHIEVING STIMULUS CONTROL

In keeping with the prescription of a programming model, visual presentations were designed to bring specific student responses under the control of specific visual stimuli. Upon presentation of such problems as the weighing of objects in air and then in water (the stimulus), the student was expected to predict the outcome - what the change in scale reading would be (the response); or when provided with an outcome as stimulus (the tearing of paper in a lesson on pressure) to indicate which way a wooden oblong would have to be deployed on the taut sheet of paper (the response). When such appropriate responses can indeed be made to the stimulus materials, stimulus control is said to be achieved.

If all we mean by "stimulus control" is that students make appropriate responses to specific stimuli, then evidence that stimulus control has been achieved must come from student responses themselves. The most direct evidence that responses were in fact systematically brought under the control of specific elements in either the visual

presentation, the verbal presentation, or both comes from an inspection of responses made during the presentations, that is, responses made on cue to the stimulus materials themselves. Based on workbook protocols obtained during program tryouts and during the experimental sessions in Study No. 1, it is apparent that the frequency of correct response to the visual presentation was quite high (approximately 85%). This suggests that responses made during the "active response" presentation were in fact effectively brought under the control of the visual stimuli. By "active response" is meant anticipatory responses to partly prompted lesson materials (e.g., predicting what would happen in a demonstration). A direct comparison of "correct-response" frequencies for this, the experimental group, and for a control group is not possible, since the control group was not required to respond actively or overtly (i.e., they made no predictions; they merely watched). Thus, the most direct evidence for comparing how well alternative treatments achieved stimulus control is not available.

Looking at the less direct, less immediate evidence of achievement test results, it is possible to compare the two treatment groups observed. The two treatment groups, it will be remembered, differed only on the basis of whether or not they responded actively. On verbal test items, the group that responded actively clearly surpassed the group that merely watched the visual and verbal presentations. On a test administered after the visual presentation only, there was a statistically significant difference in gain scores. As noted in the left-hand part of Table 1, the active response group outperformed the "passive" watchers. Further, as noted in the right-hand part of Table 1, on tests administered at various intervals after both the visual and verbal presentations were completed, the differences in gain scores observed between the two groups became progressively larger. While the gain scores for the active response groups declined moderately from the immediate test to the two-week delayed test to the four-month delayed test, the gain scores for the passive watchers declined sharply. The longer the delay in measuring retention, the more clearly was the active response group favored.

Table 1

Comparison of Gains in VERBAL Test Scores
for Active Response and Non-Active Response Groups
(total score possible = 17 points)

	Test After Visual Presentation Only		Immediate Posttest		Two Week Delayed Test		Four Month Delayed Test	
Groups	Mean Gain	S. D.	Mean Gain	S. D.	Mean Gain	S. D.	Mean Gain	S. D.
active response	3.56	(2.81)	4.78	(3.00)	4.33	(3.07)	4.00	(2.45)
non-active response	1.22	(3.30)	3.17	(2.36)	1.61	(2.57)	.58	(2.18)
Analysis of difference in gains between groups	F=4.71* df=1/30		F=3.11 df=1/30		F=7.61** df=1/30		F=11.32** df=1/20	

**significance at the 1% level; *significance at the 5% level

These results showing the beneficial effect of active responding both on acquisition and on retention are not particularly novel. They are consistent with majority findings from a large body of research on "participation techniques" (Allen, 1957). What is novel, however, is the extension of these findings to presentations that include programmed, solely visual lessons designed to teach verbal concepts. These lessons were programmed in such a fashion as to bring student responses systematically under the control of the non-verbal, visual stimulus materials. The evidence reported here indicates that for this purpose active responding is superior to passive viewing.

DATA SUGGESTING POSSIBLE ROLES FOR VISUALS IN INSTRUCTION

While achievement test results bear only indirectly on whether or not stimulus control is attained, they do bear directly on whether effective instructional strategies have been devised. On the strength of the results obtained in Study No. 1, that is, (1) that non-significant differences in total test scores between visual and verbal treatments were obtained and (2) that relatively high achievement levels were obtained for both treatments, it is apparent that programmed discrimination practice involving solely visual events can effectively teach verbal concepts and principles. In reaching this objective, no differences between visual and verbal presentations were observed on total test scores (see Table 4 on page 12). However, differences in the relative effectiveness of the visual and verbal presentations were revealed by separate analyses based on scores on either visual or verbal test items. These differences will be described in the sections to follow.

Interactions Between Stimulus Mode, Response Mode, and IQ

As measured by verbal test items only and noted in Table 2, there was a significant interaction in Study No. 1 between IQ and mode of stimulus presentation. While above average students appear to have profited more from the verbal presentation than from the visual presentation, below average students tended to profit more from the visual presentation. (In subsequent t-tests only the former finding proved statistically significant.)

Table 2

Comparison of Gains in VERBAL Test Scores
for High and Low IQ Students
Receiving Either a Visual or a Verbal Program
(total score possible = 22 points)

	Mode of Stimulus Presentation			
	Pictorial		Verbal	
IQ	Mean	S. D.	Mean	S. D.
High	2.5	(2.5)	4.8	(3.4)
Low	4.4	(3.1)	3.6	(3.7)
Analysis of Interaction		F=4.56* df=1/76		

*significance at the 5% level

Although the results favoring a visual presentation for below average students failed to reach statistical significance, they are consistent with findings of other studies and are therefore suggestive (Kanner, Runyon, & Desiderato, 1954; Gibson, 1947; Vernon, 1946). Moreover, in Study No. 2, a statistically significant interaction was observed between IQ and mode of response (see Table 3). One group of students made active, verbal responses (multiple-choice options) to a visual presentation. A second group made active, visual responses (multiple-choice pictorial options) to a comparable visual presentation. While above average students profited more from responses to verbal options than to pictorial options, the reverse was true for below average students.

Table 3

A Comparison of Delayed Test Scores for High and Low IQ Ss in the Pictorial and Verbal Response Groups

	Mode of Response			
	Pictorial		Verbal	
IQ	Mean	S. D.	Mean	S. D.
High	27.4	(5.96)	31.9	(6.61)
Low	25.4	(9.68)	17.7	(5.06)
Analysis of Interaction		F=6.02* df=1/32		

*significance at the 5% level

These findings from Study No. 2 showing an interaction between IQ and mode of response parallel the findings of Study No. 1 showing an interaction between IQ and mode of stimulus presentation. Together they suggest that learning of abstract concepts in science (even when it is measured by verbal test items) becomes easier for below average students when it is based on concrete, visual stimulus materials and on concrete, visual responses to visual presentations. On the basis of the individual

differences observed, programmed visual lessons in science appear to be less difficult than programmed verbal lessons. In support of this view additional data will now be reported that, unlike the data just reported, cut across ability levels.

Transfer From Learning Situation to Testing Situation

It might generally be expected that transfer would be facilitated from the learning situation to the testing situation the greater their similarity (Hartman, 1961). Not surprising, therefore, is the finding in Study No. 1, summarized in the left-hand part of Table 4, that the solely visual experience (compared to the verbal experience) led to superior performance on visual test items. Nor was it surprising that the verbal lesson, consisting both of verbally described concrete examples and abstract statements, proved a more effective prior experience for the relatively more abstract, verbal items than it did for concrete pictorial items. While the verbal lesson did lead to successful performance on the verbal test items, it did not prove to be superior to the visual lesson in this regard (see the right-hand part of Table 4). Experience with concrete, visual examples in the visual lesson allowed for successful transfer either to concrete, visual test items or to abstract, verbal test items.

Table 4

Comparison of Gains on Visual and Verbal Tests
for Students Receiving Either a Visual or a Verbal Program

	Mode of Testing			
	Visual Test[1]		Total Test[2]	
Mode of Presentation	Mean Gain	S. D.	Mean Gain	S. D.
Visual Only	2.35	(2.98)	5.8	(4.4)
Verbal Only	.95	(2.81)	5.1	(5.0)
Analysis of Difference in Gains Between Groups	F=4.55* df=1/76		F=.41 df=1/76	

[1] total score possible = 16 points

[2] total score possible = 36 points including verbal test items

*significance at the 5% level

Concept acquisition based on the experience provided in the programmed, solely visual lesson appears to have facilitated transfer to either a visual or a verbal criterion test. In contrast, concept acquisition based on a programmed verbal lesson appears to have facilitated transfer less readily to the visual criterion test than it did to the verbal test. It appears, on the basis of this difference in findings for visual and verbal lessons, that for transfer to occur, similarity between learning situation and testing situation may be less important when learning is based on visual (pictorial) materials.

Transfer From One Learning Situation to Another

The effectiveness of the visual presentation can be measured not only by the transfer effects it had on a subsequent testing situation but also by the transfer effects it had on a subsequent verbal learning experience. An effective integration of self-contained, programmed visual lessons and self-contained, programmed verbal lessons appears to have been achieved when the visual presentation preceded the verbal. As shown in the achievement results of Table 5 from Study No. 1 and completion time data in Table 6 from Study No. 2, the visual/verbal order of presentation excelled the verbal/visual order.

Table 5

Comparison of Gains in VERBAL Test Scores
for Students Receiving Different Orders of Presentation
(total score possible = 22 points)

	Immediate Posttest		Two Week Delayed Test		Four Month Delayed Test	
Order of Presentation	Mean Gain	S. D.	Mean Gain	S. D.	Mean Gain	S. D.
visual/verbal	5.48	(3.23)	4.71	(3.42)	5.36	(2.50)
verbal/visual	3.05	(4.19)	3.09	(4.17)	2.50	(3.92)
Analysis of difference in gains between groups	F=5.19* df=1/20		F=1.97 df=1/20		F=5.69* df=1/24	

*significance at the 5% level

In Study No. 2, with "time-to-complete" the self-paced verbal lesson as the dependent measure, it was shown that students took less time to complete a verbal program when it followed rather than preceded a visual lesson. The data from both studies, thus, suggest the facilitating effect a programmed, visual presentation has on a subsequent verbal learning experience. (Data available in the original report suggest that this finding was not due to the added learning opportunity provided by prior exposure to the visual lesson.)

Table 6

A Comparison of "Work Rate" Means
for Visual/Verbal and Verbal/Visual Groups
on the Verbal Programs+

Order of Presentation	Mean "Work Rate" (in minutes)	S. D.	N
visual/verbal	43.0	(4.88)	18
verbal/visual	46.7	(5.26)	18
Analysis of difference between groups	F=5.12* df=1/32		

*significance at the 5% level +pictorial response group only

These findings are interpreted to mean that concepts are more readily acquired when responding to concrete, visual stimulus events is made to precede responding to more abstract, verbal events. Concepts were, it is true, acquired on the basis of the visual experience alone and apparently without difficulty. The more abstract and technical explanations embodying the concepts were, however, more readily and completely acquired from a verbal presentation when it followed rather than preceded the visual presentation.

DISCUSSION

What can be made of the three groups of findings just discussed? One group of findings suggests that below average students learn concepts more easily by means of discrimination practice based on visual stimulus events and visual (pictorial) response options. A second group of findings suggests that when concepts are learned through discrimination practice with visual stimulus events, the similarity between learning situation and testing situation may not be, as is often the case, as important for transfer to occur. A third group of findings suggests that positive transfer effects from one learning situation to another are more likely to be obtained when learning based on a visual experience precedes learning from a verbal experience than when the reverse order is followed. Based on all three groups of findings presented here, how are the advantages visuals seem to provide to be interpreted?

The results which require interpretation are these: why is visual experience easier than verbal experience (as evidenced by the fact that below average students tend to profit more from it than from the verbal experience); and why does visual experience tend to facilitate transfer across modes more readily than does verbal experience?

Difficulty Level of Visual Experience

(a) Due to everyday experience with shapes, colors, sizes, etc., responses to attributes of physical objects and events are generally at high strength. On the other hand, responses to verbal symbols for the same phenomena, or for abstract referents, are not likely to be at equally high strength. Because of these differences in response strength, the relative cue-value of visual and verbal examples is likely to differ. As a result, the appropriate discriminations and generalizations on which the acquisition of concepts depends, are apt to be more difficult when they are based on verbal rather than on visual examples.

(b) The objects or events in visual examples rarely consist of single attributes to which students must respond. More often than not they consist of such phenomena as: changes in attributes as, for example, a change in color or size; causal relations, as for example, an apparent

loss of weight when an object is submerged; comparisons of attributes, as for example, the relative magnitude of the forces being applied at the two ends of a lever; long sequences of events, as for example, the assembly of coils in an electric motor; etc. Visual stimuli in science demonstrations are thus not single, simple stimuli, but often consist of dense patterns, complex combinations, or chains of stimuli. The more complex the patterns, the combinations, or the chains, the more difficult are responses to them apt to be. In connected discourse subject matter, science for example, verbal stimuli are also rarely single words; most often they consist of chains of words forming sentences of varying degrees of complexity. Difficulty of response to sentences is thus likely to be greater than the difficulty of response to single words. The question arises, "Is the visual 'sentence' then any <u>less</u> difficult than the verbal sentence?" It is assumed here that, because of the lesser difficulty level of the separate components of the visual, concrete "sentence," the complex of visual stimuli is likely to be still less difficult than the complex of verbal stimuli.

(c) The value of a stimulus for cuing a correct response is apt to be a function of how univocally stimulus and response are related. Verbal stimuli (words) are apt to have more associations than are visual stimuli and response competition, as a result, is therefore more apt to occur. The cue-value of verbal stimuli is thus likely to be less dependable.

(d) There is evidence from research on the concept learning process which suggests an explanation for the relative ease of the visual lessons (Bruner, et al., 1956). Bruner found that, when students are required on their own to <u>arrive at</u> a concept, it is easier for them to categorize attributes of phenomena than to verbalize the principle. Unlike traditional studies of concept learning in which concepts are arrived at inductively by the student without guidance (save for that provided by the definition of the task), induction of concepts in this study was guided. The task required of the student in the visual lesson was essentially a guided, categorizing task. Students were required to categorize pictorial options (portraying outcomes) as being the same as or different from outcomes they had already seen demonstrated. The task of the student in the

verbal lesson however was, by definition, more highly verbal. Thus, the issue resolves itself into one of the relative difficulty of the two tasks: guided categorizing of physical attributes vs. guided verbalizing of principles concerning physical phenomena. Concept formation studies, like the Bruner study, suggest the lesser difficulty of the former task.

Transfer From Visual to Verbal Experience

(a) The observed superiority of the visual/verbal order of presentation, as measured by achievement results in Study No. 1 and latency data in Study No. 2, suggests a facilitating role for visual materials when they precede verbal materials covering the same concepts. There is evidence from research on paired-associate learning that an optimum condition is obtained when visuals are in the stimulus position and words in the response position (Lumsdaine, 1958; Kopstein & Roshal, 1954). Conflicting findings are also reported from other studies using different tasks (Bern, 1958). There is also evidence from research on procedural learning that prior visual familiarization with parts of equipment facilitates subsequent learning to select and use the parts (Jaspen, 1950; Wulff, 1954).

The learning that occurred in this study, unlike that in the two sets of studies just mentioned, involved the acquisition of concepts, first on the basis of a solely visual lesson and then again on the basis of a purely verbal lesson. The technical language and the long verbal chains describing concepts appear to be better acquired when they follow rather than when they precede a visual demonstration. This appears to be not unlike the frequent experience in everyday life where words are learned for the concrete objects and events around us. Our experience of visualizing words is a much less frequent occurrence. One possible explanation of the superiority of the visual/verbal order of presentation in the classroom is that it capitalizes on a well established learning set.

(b) The latency data of Study No. 2 indicated that work rates on the verbal program were reduced when it followed the visual program. This suggests that generalization occurred from visual to verbal experience. To account for this generalization across modes, it may be pointed out that verbal responses to physical dimensions of the visual events are most likely

already in the student's repertoire. Indeed, they are likely to be at high strength. Thus, it is highly probable that during the visual presentation verbal responses were made (covertly). Such verbal responses are thus likely to have mediated the generalizations that occurred from visual lessons to the subsequent verbal lesson (or to subsequent verbal testing). With visual responses to verbal events likely to be at relatively low strength, it is thus not surprising that they are not likely to be available to mediate generalization from verbal learning to visual testing.

CONCLUSION

Complex and hignly abstract concepts and principles can be acquired on the basis of programmed, solely visual demonstrations. To rely on solely visual lessons for these purposes, however, results in marked inefficiency. Study No. 1 attempted to test the limits of what could be done with a solely visual lesson. While it has been amply demonstrated that concepts in science can be learned from such lessons, it is also evident that considerable savings in time could have been had by even a moderate use of words during the presentation. Subsequent experience with programmed demonstrations has shown that, even if language is introduced, the advantages of a lesson using concrete, visual materials is not lost if the language used describes concretely, rather than explains, what is occurring (as in Study No. 2). A single word, as has been aptly put, can be worth a thousand pictures.

Words serve an important cuing role when incorporated into a visual presentation. They serve other functions when they follow it. The data obtained in this study suggest that students can answer verbal items based on programmed, solely visual lessons. What a subsequent verbal experience appears to accomplish over and above this experience is the facilitation of longer verbal chains and the use of more sophisticated technical language to describe and explain the same phenomena. As educators, we <u>may</u> be content if students demonstrate mastery of concepts without the use of such technical language. Ultimately, however, it is

probably more expedient and practical for them to master this language so that continuities and discontinuities among principles may be better understood and so that students can come to communicate with others. For these reasons, visual and verbal experience are perhaps best integrated or combined. On the basis of the results of the present study, a visual/verbal order appears to constitute an effective combination for this purpose.

The visual/verbal order of presentation is optimally effective when the visual portion is designed, on its own, to teach the concepts to be acquired. Through discrimination practice based on pictorial events and on pictorial response options, concepts are acquired and the subsequent verbal experience rendered less difficult.

The use in these two studies of the visual stimulus mode, the visual response mode, and the visual/verbal order of presentation offers a paradigm for integrated, full length televised or film presentations and for single concept films integrated with other media of instruction.

INSTRUCTIONAL STRATEGIES INVOLVING VISUALS

Visual demonstrations were used in the two studies described in this report to meet one particular type of instructional objective, namely, to teach student understanding of science concepts and principles. Students were, for example, expected to be able to define the term "pressure" or to compute the amount of pressure exerted or to state what the relationship between "force" and "pressure" was. The visual presentations were designed to implement an instructional strategy suitable for this objective. Had the instructional objective been different, say, to teach students how to make observations during the conduct of an experiment or to recognize examples in nature illustrating the principle being taught or how to perform the same experiments being demonstrated, other demonstrations would have been prepared and other responses to them practiced as called for by the strategy suitable for these differing objectives.

What role can visuals play in a strategy employed specifically for teaching concepts and principles? To see how visuals might fit in an instructional strategy suitable for this purpose, some general comments on strategy formulation may be helpful.

General Comments About Instructional Strategies

When instructional objectives are adequately stated, they include a specification of: (a) end-of-course stimulus contexts under whose control responses are to be brought, e.g., a student being able to provide a definition in response to the verbal question -- "what do we mean by pressure" and (b) the response (or classes of responses) to be made, e.g., "pressure = force divided by area." Suitable instructional strategies must specify the kind of learning experience that will lead to the fulfillment of such objectives.

The general aim of an instructional strategy is to create the kind of learning experience that will ultimately lead to the criterion performance either on a test or beyond the classroom as called for by instructional objectives. Strategy formulation might be based on the

assumption that the transfer of learned responses from the learning situation to the criterion situation, would be expected to be optimally facilitated the more closely the two situations are alike. That this is not an invariant condition, however, is amply attested to by data from the present study, i.e., pictorial responses to pictorial stimuli facilitated student performance on a criterion test that contained verbal test items calling for verbal responses. Criterion performance <u>in</u> the learning situation and criterion performance <u>beyond</u> the classroom may thus vary from virtual identity to non-identity. The nature of some possible variations will be explored below.

What prescription for lesson construction must a strategy provide? To meet instructional objectives, strategies involving either words or pictures must specify: (a) the stimulus contexts in the "learning situation" under whose control responses are to be brought; (b) the responses to be brought under control; and (c) the conditions and techniques for bringing such control about. Decisions about each of these three sets of specifications are based on the assumption that successful performance in the particular kind of learning situation devised will facilitate successful criterion performance beyond the classroom. This assumption holds whether stimulus contexts used in the learning setting and the responses practiced are identical with those in the criterion situation or whether they differ markedly from each other.

(a) <u>stimulus contexts</u>. - The anticipated outcome of a learning experience is that responses come under the control of a simple stimulus or classes of stimuli (in whatever mode). In the case of concept learning, this means that students learn to make the same response to equivalent classes of stimuli. The driver learns to stop at all red lights <u>or</u> to signs that read "stop" <u>or</u> to a policeman's signal. Or the student can respond on a test indicating that he has learned that objects weigh less in water than in air, no matter what their shape or size. He can do this whether the test item is presented pictorially or verbally. These are criterion performance outcomes (on a test or outside the classroom) resulting from a learning experience in the classroom.

Criterion performance, in the case of concept learning, consists of one of a class of functionally equivalent responses in the presence of one of a class of functionally equivalent stimuli. To be capable of such a criterion performance, the student must practice the same or functionally equivalent responses in the presence of a functionally equivalent context provided in the classroom. The learning context may be identical with the criterion context, for example, responding to a program item requiring a written definition of the word "pressure." It might be substitute context, possibly bearing some measure of similarity to the criterion context (e.g., everyday language used instead of technical language). Or it might be qualitatively different from the criterion context. It might, for example, be visual demonstrations of "pressure" phenomena (e.g., the same total force, as represented by a given number of blocks, distributed over different areas), even though the criterion performance is a verbal test (as was the case in this study).

Stimulus contexts in the learning situation and in the criterion situation can differ in terms of: (1) the modality in which they are presented; for example, pictures used in the learning situation when words or symbols constitute the criterion situation (e.g., the number line used to teach addition and subtraction of positive and negative numbers) or the converse; (2) the fidelity with which one reproduces the other (within the same modality); for example, a real object represented by a model in the learning situation; or (3) the comprehensiveness with which learning situation samples the elements of a criterion context.

Because it is desirable that transfer from learning situation to criterion situation be optimally facilitated, emphasis might therefore be duly placed on achieving maximal similarity between the two situations. Accordingly a strategy might call for use of a learning context similar to that in the criterion situation. As exemplified by the case of visual contexts used in the present studies, other considerations might enter. Some of these other reasons for selecting a visual learning context, even though the criterion context is verbal, will be detailed in a succeeding section.

(b) responses. - The distinction between "criterion" and "learning" situations applied to stimulus contexts under whose control responses are to be brought applies as well to responses. Responses made in the learning situation may vary from identity to non-identity with the responses to be made in the criterion situation. Differences between the two situations may be a function either of: (1) the topography or locus of a response (for example, practicing a verbal response when the criterion performance requires a non-verbal motor response); (2) the mode of response (for example, practice in recognizing a correct response when construction of a response is the goal); or (3) the response task posed the learner; (for example, in the learning situation, the learner's task might be to construct a sentence, whereas in the criterion situation, his task might be to complete a sentence; or in the learning situation his task might be to evaluate the correctness of someone else's performance as a means of preparing him subsequently to engage in it himself).

Responses selected for practice in the learning situation (however different they may be from the criterion response), must be capable of resulting in criterion performance. In the present study, multiple-choice responding to pictorial options resulted in a criterion performance consisting of responses to test items representing a range of response types including pictorial, verbal, multiple-choice, and constructed responses. Thus, it is apparent that the response practice devised in this study facilitated transfer across modes such that students were prepared for the specified criterion performance. A rationale for a strategy calling for the use of pictorial responses during learning even though criterion responses were verbal, will be offered in a succeeding section.

(c) conditions and techniques for gaining response control. - The ultimate objective of a strategy is to bring criterion responses under the control of criterion contexts. The strategy first specifies the learning contexts and the learning responses, which are judged capable of producing the end-of-course criterion performance. Not only are stimulus contexts specified, but stimuli that are used merely to produce responses are also specified. For example, a visual stimulus may be employed, not because we wish responses to be brought under its control

(thus serving as a context). Rather it may already possess such control and we may wish control to be transferred from it to other stimuli. In this capacity it serves only as a cue. Thus, in its role as a cue a visual may be used to facilitate transfer of control to some other stimulus. Strategy considerations in selecting visuals for this role would involve their capacity, relative to that of verbal cues, for example, for cuing particular responses. It is apparent, therefore, that strategies must specify not only criterion learning contexts and responses but also all other learning responses and stimulus cues on which criterion learning performance is contingent.

Other strategy specifications would include a description of the conditions under which learning responses are brought under the control of learning contexts so that criterion performance is indeed assured. Specifications of conditions of response practice that can bring this about include a determination of: prompting strength at various stages of learning; amount of distribution of practice; how the acquisition of necessary discriminations and generalizations can be facilitated, etc.

It is apparent that criterion performance in the learning situation and criterion performance at the end of the course (whether on a test or on the job) may differ either with respect to stimulus contexts or with respect to responses. However different they may be, the strategy calling for a particular learning experience is designed in such a way as to bring about criterion performance whether on a test or beyond the classroom or training setting.

As revealed by the data of the current study, what are some of the roles visuals can play in such strategies?

Role of Visuals in Instructional Strategies

Three principal roles may be described for visuals. In an earlier report (Gropper, 1963b), a distinction was made between criterion and

intermediary visuals. Criterion visuals are those that appear in the criterion situation and are the stimulus contexts to which the student is expected to respond. To bring appropriate responses under their control, they may appear in the learning situation and, in addition to being criterion contexts, they also serve as learning contexts. For example, in order to be able to identify laboratory apparatus, the actual equipment might be used in the learning situation and students given practice in identifying it. Because visuals are integral to the criterion situation, they are used in the learning situation so that the responses acquired there will transfer to the criterion situation. This is one role visuals can play.

In the earlier discussion of visuals, intermediary visuals were described as those that already possess stimulus control over responses to be practiced. They are not integral to the criterion situation and hence do not constitute criterion stimulus contexts. Although not part of the criterion situation, they are used in the learning situation so that control may transfer from them to the stimulus contexts that are part of the criterion situation. For example, pictures to which students can respond with an appropriate identifying label (the pictures thus possess stimulus control) may be used to teach reading. The student comes to make the appropriate response (cued by the picture) to the printed word. Stimulus control is thus transferred from the picture to the word. This is the second role pictures may play. In this role as a cue, which merely produces a response so that another stimulus may gain control of it, visuals play an intermediary, instrumental, or practical role.

In the second role just described, control of a specific response is passed from one stimulus to another, with the two sets of stimuli being topographically different. For example, control over oral reading responses passing from a picture to a printed word. In a third role, also an intermediary role, topography of stimulus and response may differ. As in the study performed here, pictorial responses to pictorial stimuli facilitated subsequent verbal responding to verbal stimuli (test items). Concepts acquired on the basis of the visual presentation generalized across modes, so that students could respond to verbal contexts (verbal test items),

even though no verbal responding was required. Despite the absence of such a requirement, it may be inferred that correct, verbal mediating responses were occurring. It is precisely because verbal responses are in fact under the control of the visual stimuli and their strength quite high that visual stimuli are used. Because of such high response strength, it is assumed, verbal mediating responses are likely to be made to the visual presentation. It is this form of mediation, it is hypothesized, that can account for the generalization that occurred across modes (from pictorial responses to pictorial stimuli in the learning situation to verbal responses to verbal stimuli in the testing situation). Had some feature or dimension of a visual presentation not had stimulus control over a mediating verbal response, then it is unlikely that generalization would have occurred from visual learning to a criterion performance requiring verbal responding (Klaus, 1965b).

What are the considerations involved in the use of such intermediary visuals (and responses to them), which may differ in modality from criterion contexts and criterion responses? Why use them instead of using actual criterion contexts and criterion responses in the learning situation?

The question may be illustrated with a practical illustration. For teaching the discriminations and generalizations that underlie concepts and principles in science, it is possible, as shown by data from two studies, to choose between visual and verbal examples. Examples in either mode provide appropriate contexts to which students must respond. Having seen a number of prior demonstrations illustrating the apparent loss of weight that occurs when objects are weighed in air and then in water, a student is then presented with a new visual context. He is shown still another object weighed in air and instructed to predict whether the reading on the scale will increase, decrease, or remain the same. The same context might be presented in words and, following a series of prior verbally stated examples, the student would be instructed to predict what would happen to still another verbally described example. Based on such response practice with either visual or verbal contexts, students in this study came to acquire the concepts and principles in Archimedes'

Law. What are the rational considerations on which a choice might be made between presentations of visual rather than verbal examples? What strategy considerations are involved?

Manipulating response difficulty. - There is evidence from both studies described in this report to suggest that science concepts are more easily acquired from visual rather than verbal examples. This was particularly true when the visual mode was used for both stimulus materials and response options. The ease that the visual mode affords in both cases, it was suggested, derives from well established associations. High strength responses are already under the control of visual stimuli and can readily facilitate concept acquisition. Whatever the interpretation, the data revealing both individual differences in learning from visual and verbal materials and the transfer-facilitating effects of visual presentations suggest that concept acquisition can be made easier through the use of visual (pictorial) presentations. To what practical uses might such a finding be put? Three possibilities suggest themselves: (a) accommodation of individual differences; (b) reduction of the difficulty level of complex subject matter; and (c) setting difficulty levels appropriate to stages of learning.

(a) accommodating individual differences. - Recently completed research by Gagné and Gropper (1965) failed to reveal any significant relationship between special aptitudes, particularly visual aptitudes, and a person's capacity to profit from visual presentations. The results of the present study do not suggest the possession of any special aptitude as calling for visual presentations. On the contrary, it would seem that it is the absence of aptitude, particularly verbal aptitude, which is the largest component in such IQ measures as Otis IQ, that does appear to call for the use of visual presentations. The evidence suggests that below average students were better able to acquire the concepts taught in both studies by means of pictorial presentations and pictorial responses than by means of counterpart verbal material. Far from possessing any special visual aptitudes, below average students can respond to visual examples because, it is suggested, they, along with

their brighter counterparts, have had considerable prior experience in responding to the concrete attributes of many physical objects and events. Such examples are therefore capable, with high probability, of eliciting appropriate responses. Doing well with visuals, far from being a special aptitude, constitutes, so to speak, an easy task.

The two studies reported here were based on the performance of eighth graders. It is reasonable to suppose that the advantages that visuals have for below average eighth graders, might also accrue to students throughout the ability distribution at still lower grade levels. Based on the assumption that at lower age levels the capacity for abstract (verbal) thought is even more diminished, visual presentations using concrete stimuli might be more readily recommended for them.

(b) reducing the difficulty level of complex material. - An instructional strategy might specify a wholly visual (or at least partly visual) presentation for below average students or for very young students as a way of facilitating learning. For complex materials, learning might be facilitated for all, regardless of ability or of age, through the use of a similar strategy. The use of the number line to teach the addition and subtraction of positive and negative numbers comes to mind as an example of such an approach. To the extent that visual techniques can be imagined, formulated, and implemented for such purposes, they might be recommended as a means of reducing the difficulty level of what would otherwise be complex and not easily acquired concepts or principles.

(c) setting difficulty levels to match stages of learning. - It is fairly axiomatic in programmed instruction that learning progresses from what is known to what is unknown, from what is easy to what is difficult. Various strategies are possible for this purpose. The difficulty level of vocabulary can be manipulated. Familiar verbal examples can be used to explicate what is new and abstract. To facilitate ease of response the mode chosen for response practice can be varied. In the REP style of programming, for example, Gropper (1965) requires production responses only after editing responses and these in turn only after recognition responses. As in the case of these various strategies, the use of visuals

in early stages of learning can similarly serve to make responses less difficult.

In the present study, the findings of two experiments have shown the advantages of visual presentations that precede rather than follow a more abstract verbal presentation. Being easier, the visual presentation appropriately comes first to match the stage of response readiness of the learner.

For any of the three purposes just described, one of the conditions of the learning experience that can be manipulated through the use of visuals is response difficulty. One of the consequences of such manipulation is the possibility of controlling the frequency of student errors. Error control is a concern because of its assumed relation to achievement. Recent results reported by Kress and Gropper (1964), support such an assumption. Based on two programs and two groups, four correlations were obtained between the number of errors committed and achievement scores. On one program, the correlations for the two groups was -.64 and -.65 and on the second program -.67 and -.70. Despite the fact that the variability of the error distributions were sharply curtailed, sizeable negative correlations were obtained indicating that the more errors students made on programs, the lower their achievement scores were. If, then, there is justifiable concern about error control, the relative ease of visual materials suggests the visual modes as another possible instrument for achieving it.

By proposing pictorial contexts and pictorial responses, the educator can formulate a strategy that can render the learning experience easier. Pictures can be used to cater, as it were, to the response readiness of the learner as this is influenced by the complexity of the material, by the student's particular abilities and experience or lack of them, or by the stage of learning he is about to enter.

The pictorial mode is selected for the learning situation not because criterion contexts are similarly pictorial, but because the conditions of learning can be altered. Intermediary visuals, rather than criterion visuals are used, because they make learning easier (Gropper, 1963b). Pictures are thus used for practical reasons.

Facilitating transfer. - To make transfer more likely, it is sometimes appropriate to build criterion contexts into the learning experience. Thus when visuals are both intermediary and criterion at the same time, transfer might be expected to be optimally facilitated. When the criterion situation contains visual contexts, it is reasonable to expect positive transfer to occur when students practice responses to identical or similar contexts in the learning situation. What of those criterion situations however, that do not contain visual contexts? Suppose a criterion test, for example, consists solely of verbal test items. What occurs when the learning situation consists of pictorial responses to pictorial contexts? On the basis of the data reported in Study No. 1, it appears that departure from similarity between learning situation and criterion situation is not nearly so crucial when programmed visuals are used to teach concepts in science.

The findings of the present study seem to indicate that when the learning experience is verbal, students do well on only the verbal test. When the learning experience is visual, students do well on both visual and verbal tests. Transfer across modes appears to occur more readily from visual to verbal than in the reverse direction. In addition, data concerning transfer that occurs from one learning situation to another learning situation also suggest the superiority of the visual/verbal direction.

It may well be that in addition to altering response difficulty, a visual/verbal order of presentation capitalizes on the well established set of associating words with visual experience. Thus it is highly likely that visual presentations produce mediating verbal responses. On the other hand, the opportunity or need to visualize our words do not seem to be as insistent in our everyday experience. Consequently the

verbal/visual order of learning or transfer from verbal learning to visual testing is not likely to benefit from mediating visual responses. The greater likelihood of verbal mediation (than visual mediation) may in part account for the superiority of the visual/verbal order of presentation and, when learning is based on visual experience, for the lesser need for similarity between learning and criterion situations.

The visual/verbal order of presentation appears to be superior to the reverse order for two reasons:

(1) Pictorial responding to pictorial material is likely to be easier (for concept learning) than is verbal responding to verbal material. Since early stages of learning are deliberately made easy, visual experience should precede verbal experience.

(2) Since the integration of words and pictures requires transfer from one to the other, the visual/verbal order of presentation is preferred. This is the order in which transfer appears to occur best.

Other Strategy Considerations Suggesting Further Research

Visuals may play still other roles in instructional strategies. Suggestions about such roles will merely be offered here, either because the data relating to them from this study are fragmentary or because the present study did not investigate them at all. They are to be considered as issues meriting further study.

(a) providing a variety of learning contexts. - Concepts and principles are more easily acquired and, perhaps better applied, when a broad range of examples is employed to teach them. One way to vary the breadth of learning contexts is to present examples in more than one stimulus mode. Data from Study No. 1 demonstrated that a visual presentation and a verbal presentation (in that order) excelled not only the reverse order of presentation but also two presentations of either the verbal

lesson or the visual lesson. Thus a mixed visual and verbal treatment proved superior to a wholly visual and to a wholly verbal one. However, since these latter two treatment conditions merely involved the repetition of the same examples in the second presentation of the lesson, the conclusion to be drawn about breadth of contexts is not so clear-cut. The comparison that needs to be made is, therefore, between a visual/verbal presentation and solely verbal or solely visual presentation that have comparable variety of examples. Should the visual/verbal presentation still prove superior, then this effect would not entirely be attributed to the manipulation of response difficulty (as discussed above). Variations in mode of stimulus presentation might then be considered to be a facilitating factor in the acquisition of a generalized response, i.e., a concept or principle. Generalization across visual and verbal examples is not likely to occur, however, unless the relevant visual stimulus dimensions have verbal responses under their control and unless these responses are at high strength. These are hypotheses for future testing.

(b) facilitating learning tasks. - It was just suggested that a mixture of visual and verbal examples might facilitate the generalization of responses to new situations. It is also suggested that it might be worth exploring the possibility that visual examples alone rather than intermingled with verbal examples might facilitate the acquisition of the discriminations and generalizations on which concepts depend. One possibility is that it might require fewer visual examples for a generalization to be built than would be the case if verbal examples were used. Should these visual examples require less time to present, there would be a decided advantage in using them. However, watching science demonstrations sometimes requires more time than reading a verbal, printed statement of an example. Advantages would have to be sought elsewhere -- for example in better retention of the concepts they illustrate.

As to discriminations, might there be advantages to using visual stimulus materials rather than verbal materials? Might they, too, not be acquired on the basis of fewer examples if the examples are visual? Might not the possibility of simultaneous contrasting of examples

(particularly with static visuals) rather than contrasting successive examples (usually the case with verbal examples) prove more effective and efficient?

The use of fewer examples on which the acquisition of generalizations and discriminations depend suggests rather paradoxically that, even though it may be easier to respond to visual examples than to verbal examples, step size may be increased. If students are brought to criterion level performance on the basis of fewer examples, each step along the way would obviously be larger.

(c) facilitating transfer. - The results presented here (successful performance on verbal test items even when learning was based on pictorial experience) indicated that transfer across modes occurred. It was hypothesized that this transfer was mediated by verbal responses. It was further hypothesized that, had not such verbal responses been under the control of the pictorial stimuli, transfer would not have occurred. Research in which strength of verbal responses to pictorial stimuli is manipulated can be designed to disclose whether concept acquisition (measured verbally) based on programmed pictorial presentation depends on such verbal mediation.

The inferior transfer from verbal learning to visual testing was further interpreted in terms of the lack of high strength visual responses available to mediate such transfer. Comparable research could be designed in which pictorial response strength is also systematically manipulated. Further meriting study are the techniques whereby pictorial responses to verbal stimuli might be brought to higher response strength. At such high strength, they might be capable of playing the mediating role they are often assumed to play.

The issues outlined above, those for which this study has provided answers and those requiring further research, it can be readily seen stem from behavioral considerations, from an analytic view of the learning processes and the variables of which they are a function. Many other issues could be suggested, but the ones described here, are restricted to those stemming from the research just completed.

SUMMARY

The integration of words and pictures in the two studies reported in this volume was accomplished quite unconventionally. In one study, an entire topic, "Archimedes' Law," was covered in a self-contained, entirely pictorial lesson and also in a self-contained, entirely verbal lesson. Students acquired all the concepts and principles making up Archimedes' Law first on the basis of one lesson and then once again on the basis of the second. In a second study involving a lesson on "pressure," only one or two concepts or principles were covered in each visual segment and then again in each verbal segment. It required all five visual segments in the lesson to teach all the concepts and principles. Similarly it took all five verbal segments to teach all the concepts and principles. Thus, the only difference between the two studies was that the lesson in the second study was segmented. What was common to both studies was the provision for the acquisition of the discriminations and generalizations underlying the concepts and principles to be taught solely on the basis of programmed visual material, solely on the basis of the programmed verbal material, and then on the basis of both sets of materials combined.

In the visual/verbal order of presentation, a student acquired the discriminations and generalizations (necessary to understand the concepts being taught) on the basis of the pictorial materials first; he then acquired them once more, in more technical language, on the basis of verbal materials. For example, on the basis of the solely visual lesson on Archimedes' Law he learned the principle that objects weigh less in water than in air. The subsequent verbal lesson taught him that there "is an apparent loss of weight" when objects are weighed in water.

This procedure whereby programmed visual lessons on their own are used to teach concepts is quite different from the conventional use of pictorial material. Typically a visual example is used to precede or to follow a verbal statement or principle or a verbally described example. Rarely are a sufficient number of visual examples used and rarely is the opportunity afforded to practice the necessary discriminations about the examples so that the relevant concept is fully acquired on the basis of

the visual examples alone. Concepts cannot in conventional uses of pictures be acquired either on the basis of the visual example(s) alone or on the basis of the verbal example(s) alone. In contrast, in the procedure used in these studies, concepts were fully acquired on the basis of either the visual or the verbal series of examples. Thus, when the recommendation is made that visuals should precede the verbal treatment, it does not mean that a single visual followed by verbal statements of principles will suffice. The concepts must be first acquired on the basis of the visual treatment (using as many examples as is needed) and only then should the same concepts be covered in the verbal treatment. The purpose of including the verbal lesson is to teach the student the technical language describing the concepts he already understands.

An efficient integration of words and pictures would appear to call for the following prescription: the use of a single concept film (using visuals) followed by verbal materials (whether in print, in lecture, or in film or televised form). Pictures and words would be serially intermixed as called for by a particular instructional strategy. Visual presentations would be designed to facilitate acquisition of the discriminations and generalizations on which understanding of concepts and principles depended. Further, pictorial responses to such presentations would be required. One role that visuals of the sort just described can play in an instructional strategy is to make concept learning easier. This strategy would be followed: (a) for students of lower verbal ability or for young students; (b) for all students when concepts to be learned are complex; and (c) for matching difficulty requirements at various stages of learning. Also, since it appears desirable that visual and verbal experience be integrated, a second role visuals can play (when they come first) is to facilitate transfer to a subsequent verbal learning experience.

Aside from the substantive findings they provided, the two studies reported here represent a systematic attempt to apply learning theory considerations to the use of visuals. They were based on an analytic look at the various roles visuals can play in instruction (e.g., cuing

responses; reinforcing responses; serving as examples to facilitate acquisition of discriminations and generalizations). Further, the studies were based on the assumption that these various roles will prove variably beneficial depending on the particular type of learning task to be facilitated. In this study, students had to learn concepts and principles. Had their learning task been different, say to learn a language, to learn how to solve problems, or to acquire motor skills, then different strategy considerations and different roles for visuals would have been devised. The optimal use of visuals thus would appear to depend on an analytic look generally at the roles visuals can play in instruction and more specifically in facilitating particular kinds of learning tasks.

These considerations stem from a behavioral way of looking at learning from pictures. Further research can provide evidence as to the adequacy of learning theory to account for such learning. Only as such evidence accumulates and learning theory becomes increasingly comprehensive can applied problems be readily solved. The quickest route to their solution, it is suggested, is through the rigorous testing of a theory, rather than the eclectic, ad hoc borrowing from learning theory and from communication theory to account for particular phenomena.

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